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***BOCCONIA FRUTESCENS* DISTRIBUTION ON  
THE ISLAND OF HAWAII**

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## ABSTRACT

*Bocconia frutescens*, or plume poppy, is a large erect shrub listed as a noxious weed by the State of Hawai'i. Surveying was conducted in 2003 to document the distribution and population densities in Wood Valley (Ka'ū District), Honomolino and Manukā (South Kona District). Ground surveying was conducted along 80 transects in addition to roadside and aerial surveying. *Bocconia* was distributed across 1,522 ha in Wood Valley, 82 ha in Honomolino, and 34 ha in Manukā. *Bocconia* was a severe pest within young (5 to 10-m tall) *Eucalyptus* plantations in Wood Valley, with fruiting individuals observed in all sampled parcels. Lower plant densities were observed in interiors of mature *Eucalyptus* forest adjacent to severely infested plantations, principally in gaps and streambeds, suggesting an affinity for high light levels and soil disturbance. Cane lands harbored mature *Bocconia*, although at a much lower density than *Eucalyptus* plantations, with less than 100 individuals/ha versus greater than 500 individuals/ha. Higher densities were observed along roadsides within cane lands. *Bocconia* was not observed within native, closed-canopy 'ōhi'a and koa forests in the adjacent Ka'ū Forest Reserve, except along one jeep trail. *Bocconia* populations in Honomolino occur in a mosaic of habitats including rangelands, 'ōhi'a forest and woodlands and residential areas. *Bocconia* at Manukā occurs primarily in 'ōhi'a-dominated native mesic forest.

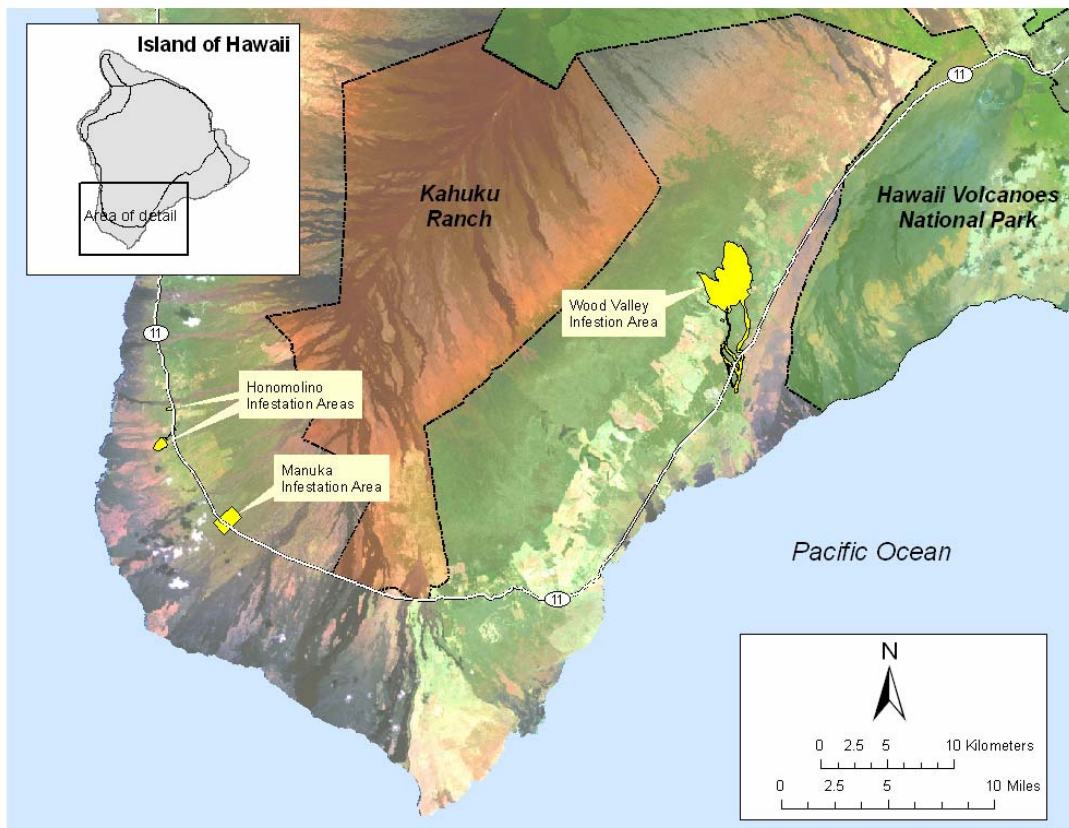
## INTRODUCTION

*Bocconia frutescens* L. (Papaveraceae), or plume poppy, is an invasive shrub listed as a noxious weed by the State of Hawai'i (HDOA 1992). *Bocconia* is native to Central and South America and the West Indies and was introduced to Hawai'i as an ornamental (Wagner *et al.* 1999, Starr *et al.* 2003). This species is characterized by a soft-wooded trunk, large lobed leaves, fast growth and copious seed production. *Bocconia* is known to occur on the Hawaiian islands of Maui and Hawai'i. A single broad infestation is documented from Maui, in primarily dry forests on the south and west slopes of Haleakalā between 490 and 1,200 m elevation (Starr *et al.* 2003). Three distinct populations were documented on Hawai'i Island in late 2002 by the Big Island Invasive Species Committee (BIISC); however, population densities and range extents were unknown at that time. This report summarizes survey work initiated in early 2003 to document the extent of *Bocconia* invasion on Hawai'i Island. The purpose of this study is to provide data for development of a strategy to manage *Bocconia* infestations on the island, and to provide baseline data for future *Bocconia* studies.

## METHODS

Surveying was conducted from April through July 2003, to document the distribution and population density of *Bocconia frutescens* in Wood Valley (Ka'ū District), Honomolino and Manukā (South Kona District) on the Island of Hawai'i (Figure 1). The study areas were selected based on known infestations identified from prior field data (Benitez 2002, BIISC 2002).

Initial ground surveys were conducted along roadsides near known infestations, and presence/absence of *Bocconia* was used to direct further sampling. Seventy-nine linear transects, totaling 30.7 km in length, were established at Wood Valley and Manukā. These transects ranged from 40 to 1,600 m in length and were placed in parcels of uniform vegetation, generally bounded by roads, or other conspicuous features such as gulches or forest. Transect width varied between three and 50 m between transects, but was uniform within individual transects. The start of each transect was determined randomly along the most accessible edge of the parcel to be sampled, using a GIS. Within sampled parcels, between one and eight transects were established and monitored. Counts of mature plants (>1.25 m or fertile) and juveniles (<1.25 m and sterile) were recorded along each transect. Population densities (plants per hectare) were calculated by dividing the number of plants found along a transect by the area sampled within the transect. These values were extrapolated across the parcel. Where multiple transects were sampled within a parcel, the counts and transect area were summed, and these values were used to calculate the parcel's density. Transects were generally representative of the parcels with respect to *Bocconia* abundance and vegetation type. One 4.3 km roadside transect was sampled in Wood Valley in mixed vegetation.



**Figure 1.** *Bocconia* infestation areas on the island of Hawai`i.

Some areas could not be thoroughly surveyed due to the difficulty of the terrain, surrounding vegetation or time constraints. In such cases ocular estimates of counts or densities were made from the ground or helicopter. Ground surveys were augmented by 4.5 hours of helicopter flight (May 14 and June 20, 2003) to locate outlying populations, survey remote areas and identify areas of highest infestation. Five relative density classes were created to facilitate sampling; these are summarized in Table 1.

**Table 1.** *Bocconia* population density classes.

No. of Individuals per Hectare	Density Class
Less than 10	1
11 – 100	2
101 – 250	3
251 – 500	4
Greater than 500	5

## RESULTS

The inventory confirmed the presence of *Bocconia* infestations in each of the three survey areas. *Bocconia* was distributed across 1,522 ha in the vicinity of Wood Valley, 82 ha in Honomolino and 34 ha in Manukā (Figure 1). *Bocconia* was found to display strong affinities for particular vegetation types and land uses, especially in Wood Valley.

### Wood Valley

The Wood Valley survey area is located northeast of Pahala and ranges in elevation from 220 to 1,030 m. Surveys were carried out along 71 linear transects totaling 21.8 km and one road-survey transect of 4.3 km (Figure 2). Helicopter over-flights were conducted May 14 and June 20, 2003 (Figure 3). With the use of a Landsat 7 image, the area was divided into parcels which could be easily identified because they were bound by roads or abrupt vegetation changes. Individual parcels were classified into six general land-use and vegetation types: alien forest, cane lands, *Eucalyptus* plantations, farm lots, gulches and native forest including part of the Ka'ū Forest Reserve.

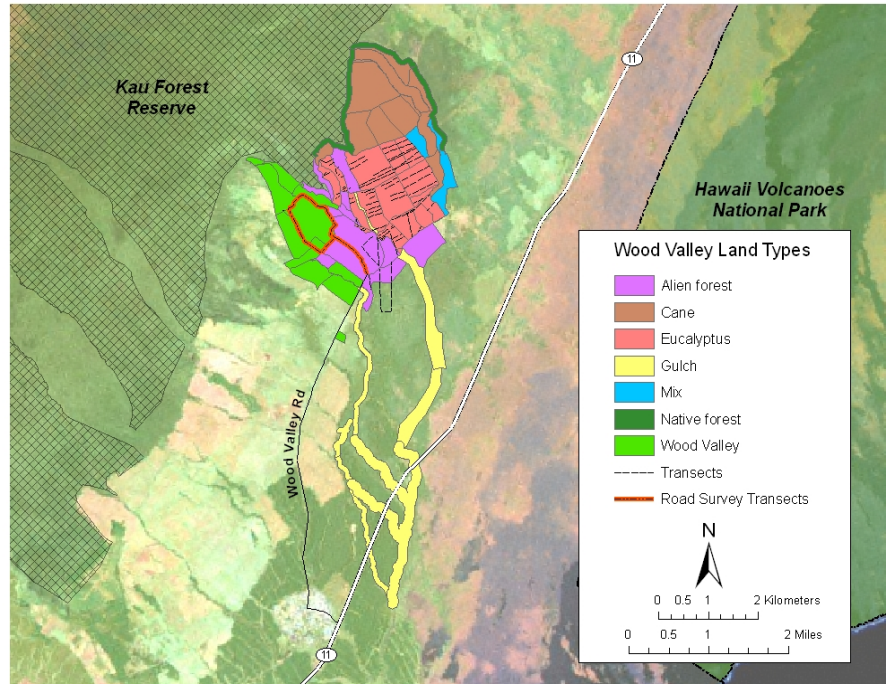
### *Eucalyptus* Plantations

These parcels, totaling 318 ha (Figure 2), were covered with young (5-10 m in height) *Eucalyptus* trees, and were generally bounded by roads. A 21-ha stand of alien forest bisects the northwestern corner plantation (Figure 4). Fertile *Bocconia* was encountered in all *Eucalyptus* parcels sampled in Wood Valley. The average density was calculated at 760 individuals/ha (Table 2) across all parcels. A total of 124 ha contained the highest population densities (>500 individuals/ha, Class 5), 15 ha had densities between 500-251 individuals/ha (Class 4), 96 ha had densities between 250-101 individuals/ha (Class 3), 39 ha had densities between 100-11 individuals/ha (Class 2), and the remaining 44 ha had densities below 10 individuals/ha (Class 1). Population densities were highest in a 29-ha parcel (5,224 individuals/ha) at 670-762 m elevation in the southwestern part of the survey area, and lowest (<10 individuals/ha) in parcels at 700-800 m elevation in the northeast quadrant (Figure 5).

### *Alien Forest*

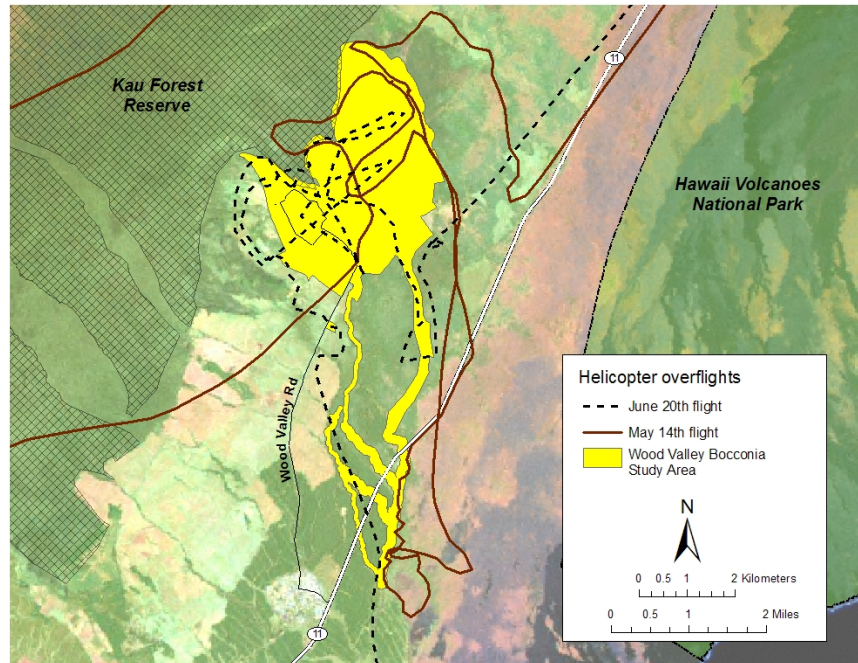
Alien forest parcels were typically tall statured (>10 m) forest dominated by exotic tree species including silk oak (*Grevillea robusta*), Formosa koa (*Acacia confusa*), two albizia species (*Falcataria moluccana*, *Albizia chinensis*) and *Eucalyptus* (*Eucalyptus* spp.). *Bocconia* was encountered across 209 ha of alien forest. A parcel of 14 ha contained the densest infestation found in this forest type, over 500 individuals/ha (Class 5). This parcel was adjacent to a heavily infested *Eucalyptus* plantation. A 21-ha alien forest parcel bounded by *Eucalyptus* near the upper elevation of the study site contained an estimated 150 individuals/ha (Class 3). However, this value may be overstated, as sampling occurred primarily along the accessible, relatively sparse edges of the forest. All remaining alien-forest parcels surveyed had *Bocconia* densities less than 100 individuals/ha (Class 2, 1), primarily occurring in gaps and streambeds. A 61-ha forest parcel to the east of Wood Valley farm lots contained an estimated 38 individuals/ha. In

this parcel, 1,400 m of transect were sampled and *Bocconia* was recorded only in a central gulch and in a forest canopy opening (40 individuals).



**Figure 2.** Overview of Wood Valley *Bocconia* distribution showing land-use classifications and survey transects. The town of Pahala is located to the south-west just outside this map.





**Figure 3.** Wood Valley helicopter over-flights conducted May 14 and June 20, 2003.



**Figure 4.** Overview of Wood Valley *Eucalyptus* plantations, looking north from ~300m above ground level. To the top right are the cane lands, and the Wood Valley Town site is beyond the left of the image. Through the center of the image runs a strip of 21 ha of alien forest. (Photo D.M. Benitez)

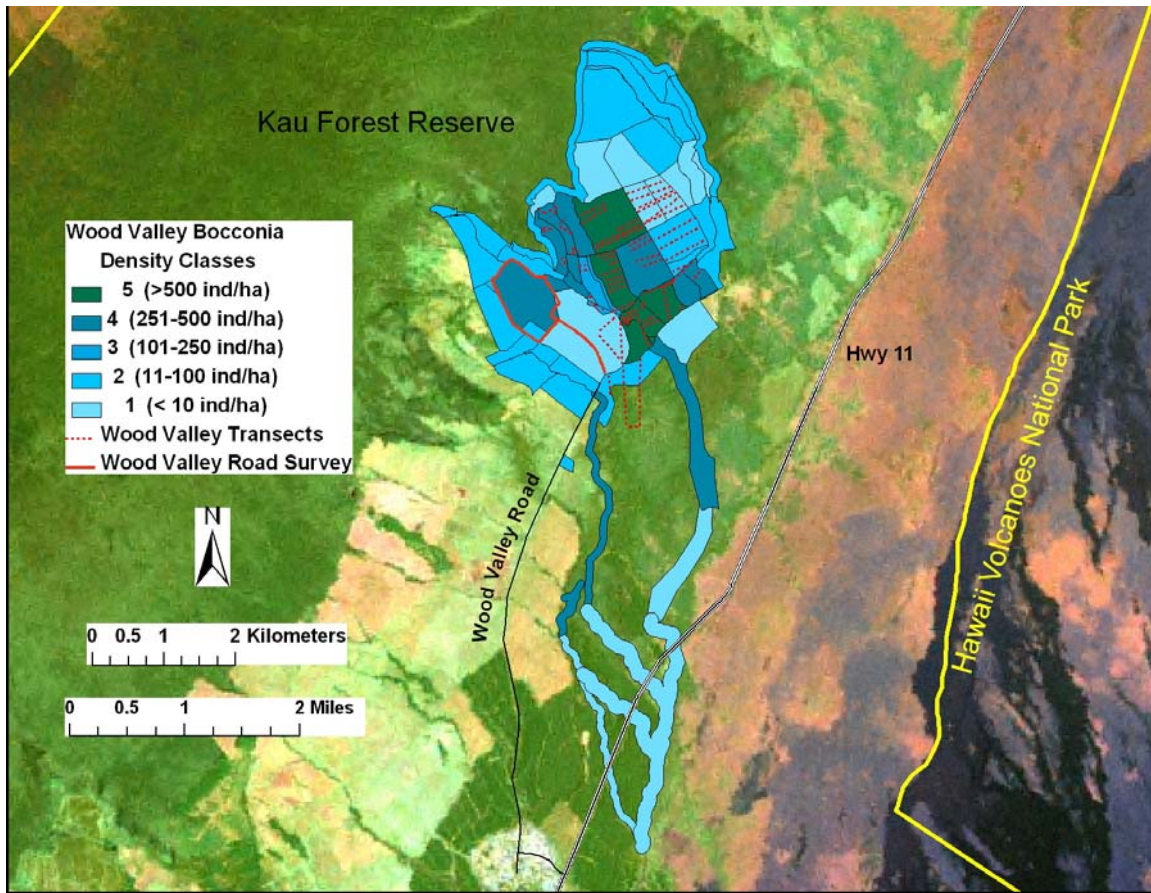


Figure 5. Wood Valley *Bocconia* population density classes.

Table 2. Extrapolated densities of *Bocconia*, based on transect counts, in Wood Valley *Eucalyptus* plantations, including a swath of alien forest bounded by *Eucalyptus*.

Land Type	Area (Hectares)	Population Density Class	<i>Bocconia</i> per Hectare
<i>Eucalyptus</i>	29.1	5	5224
<i>Eucalyptus</i>	15.5	5	1742
<i>Eucalyptus</i>	21.6	5	578
<i>Eucalyptus</i>	57.5	5	562
<i>Eucalyptus</i>	2.0	4	381
<i>Eucalyptus</i>	13.1	4	275
<i>Eucalyptus</i>	11.9	3	179
<i>Eucalyptus</i>	43.2	3	125
<i>Eucalyptus</i>	13.3	3	125
<i>Eucalyptus</i>	12.9	3	125
<i>Eucalyptus</i>	14.5	3	110
<i>Eucalyptus</i>	18.4	2	31
<i>Eucalyptus</i>	21.0	2	31
<i>Eucalyptus</i>	6.6	1	5
<i>Eucalyptus</i>	37.5	1	2
Alien Forest	21.4	3	150

### **Cane Lands**

*Bocconia* was distributed across 310 ha of cane lands in Wood Valley with an average population density of 27.5 individuals/ha (Table 3), between 840 and 975 m elevation. The southwestern parcels (105 ha) contained densities below 100 individuals/ha (Class 2, 1). (Figure 5). *Bocconia* was less abundant in the remaining 205 ha of canelands to the north and east, densities were less than 10 individuals/ha (Class 1). Ground and aerial surveys encountered *Bocconia* more frequently along roadsides than in cane interiors.

**Table 3.** *Extrapolated densities of Bocconia, based on aerial surveys, in Wood Valley cane fields*

Land Type	Area (Hectares)	Population Density Class	<i>Bocconia</i> per Hectare
Caneland	18.6	2	85
Caneland	7.6	2	80
Caneland	36.9	2	70
Caneland	19.1	2	50
Caneland	31.1	2	40
Caneland	15.3	1	10
Caneland	36.3	1	10
Caneland	18.1	1	10
Caneland	71.8	1	10
Caneland	14.5	1	10
Caneland	40.8	1	10

### **Native Forests**

Native forests were typically closed canopy `ōhi`a (*Metrosideros polymorpha*) forests, with a dense understory of native ferns and alien and native shrubs. Small patches of koa (*Acacia koa*) were also found throughout the study site. *Bocconia* was not encountered in native forests within the Ka`ū Forest Reserve. An estimated 1.5 ha of forest was surveyed in the vicinity of two populations previously documented in 2002 (BIISC) at 1,005 m elevation, and 1.1 km of trails were surveyed between 990-1,060 m elevation in the Ka`ū Forest Reserve.

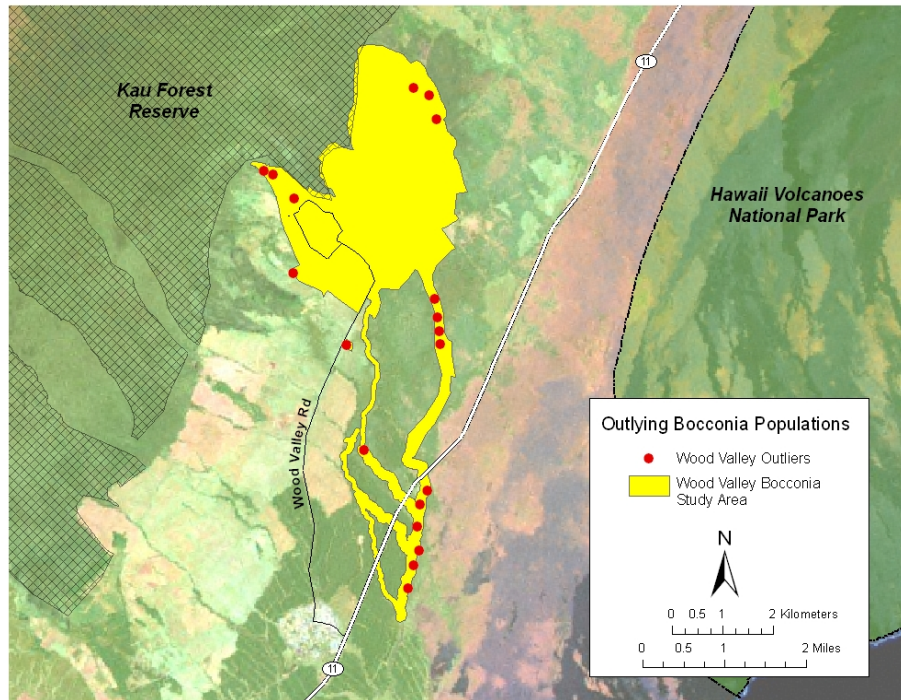
*Bocconia* formed locally dense patches with more than 100 individuals in open koa forests adjacent to *Eucalyptus* parcels, and extended 30 m into `ōhi`a-dominated forests at 880 m elevation. *Bocconia* occurred along the edges of native mesic forest below 980 m elevation outside of the Ka`ū Forest Reserve, and at 850 m elevation along the eastern edge of the cane lands and *Eucalyptus*. *Bocconia* could not be detected aerially in native closed canopy forest due to dense vegetation cover.

### **Wood Valley Town Site**

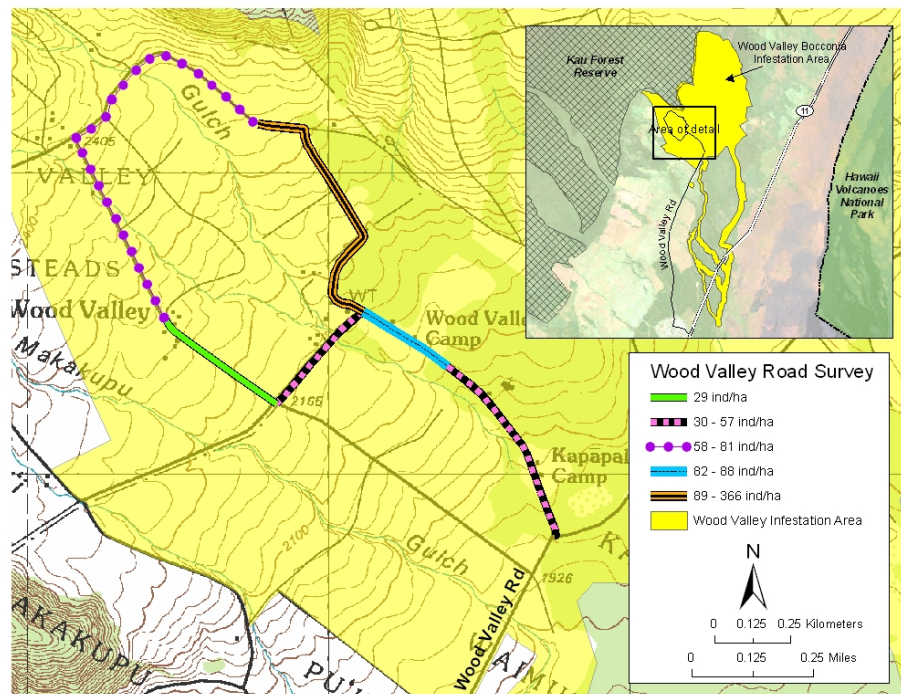
The Wood Valley town site consisted of a mosaic of habitats including pastures, woodlands, forests, residential lots and agricultural lots. Approximately 588 ha were surveyed and *Bocconia* was distributed over 282 ha in this area (Figure 7) at elevations between 550-900 m (Table 4). *Bocconia* was most abundant in the eastern half of Wood Valley. A 58-ha parcel of residential and agricultural land located in the center of the valley contained an estimated 150 individuals/ha. A survey of 4.3 kilometers of principal roadsides in Wood Valley documented *Bocconia* at densities between 29 and 366



individuals/ha, with an average of 94 individuals/ha. Locally dense clusters of 10-200 plants were observed from this road.



**Figure 6.** Outlying *Bocconia* populations in the Wood Valley area.



**Figure 7.** Roadside surveys and population densities in the Wood Valley town site

*Bocconia* was less abundant in the western part of the Wood Valley study area. Ninety five hectares in Wood Valley contained densities of *Bocconia* between 10-100 individuals/ha, and an additional 190 ha contained *Bocconia* at less than 10 individuals/ha. Across this range, *Bocconia* was observed from roadside and helicopter, in small clusters of one to 50 plants.

Nineteen outlying clusters or populations were identified along the western edge of Wood Valley, as well as elsewhere along the infestation edges. These were separated from each other by at least 100 m (Figure 6). The habitat in which these populations occurred included gulches, pastures, abandoned cane fields, and forest.

**Table 4.** *Extrapolated densities of Bocconia, based on transect counts and aerial surveys, in Wood Valley town site.*

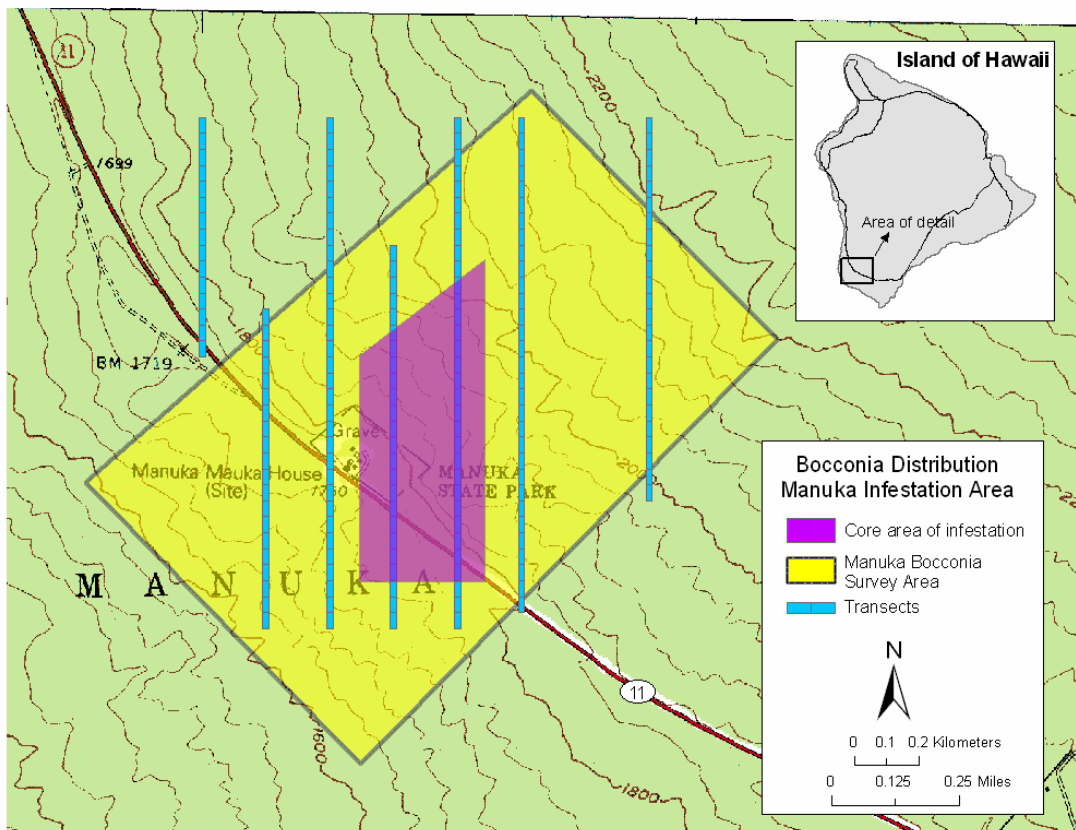
Land Type	Area (Hectares)	Population Density	<i>Bocconia</i> per Hectare
Residential/Agricultural	58.2	3	150
Alien forest, Tall grass	33.9	2	50
Grassland	13.9	1	8
Alien forest, Tall grass	7.8	1	4
Residential/Agricultural	13.6	1	3
Residential/Agricultural	4.0	1	3
Grassland	5.6	1	2
Residential/Agricultural	33.5	1	2
Residential/Agricultural	25.9	1	1
Residential/Agricultural	30.1	1	1
Agricultural	24.7	1	1
Residential/Agricultural	15.6	1	1
Residential/Agricultural	15.2	1	1

### **Makai (Ocean-side) Gulches**

Scattered *Bocconia* were encountered at a minimum elevation of 350 m in the Ka`ala`ala Gulch, approximately six kilometers south of Wood Valley (Figure 5). *Bocconia* was common in gulches throughout Wood Valley, but infrequent in gulches makai (ocean-side) of Highway 11. At the southernmost point, *Bocconia* in these gulches was as close as 3.5 km from the western boundary of Hawai`i Volcanoes National Park (HAVO).

### **Manukā**

Seven transects, totaling 8.9 km, were surveyed at Manukā within native tall-statured mesic forest with an area of 216 ha. A 34-ha infested area was identified with a population density of 30 individuals/ha (Class 2) (Figure 8). The elevation for the infested area ranged from 540 to 610 m. A total of 7.2 km of transects were surveyed beyond the core infestation area, but *Bocconia* was not encountered. Helicopter over-flights confirmed the observed distribution pattern of *Bocconia* limited to the core; *Bocconia* was easily seen though the sparse `ōhi`a canopy.

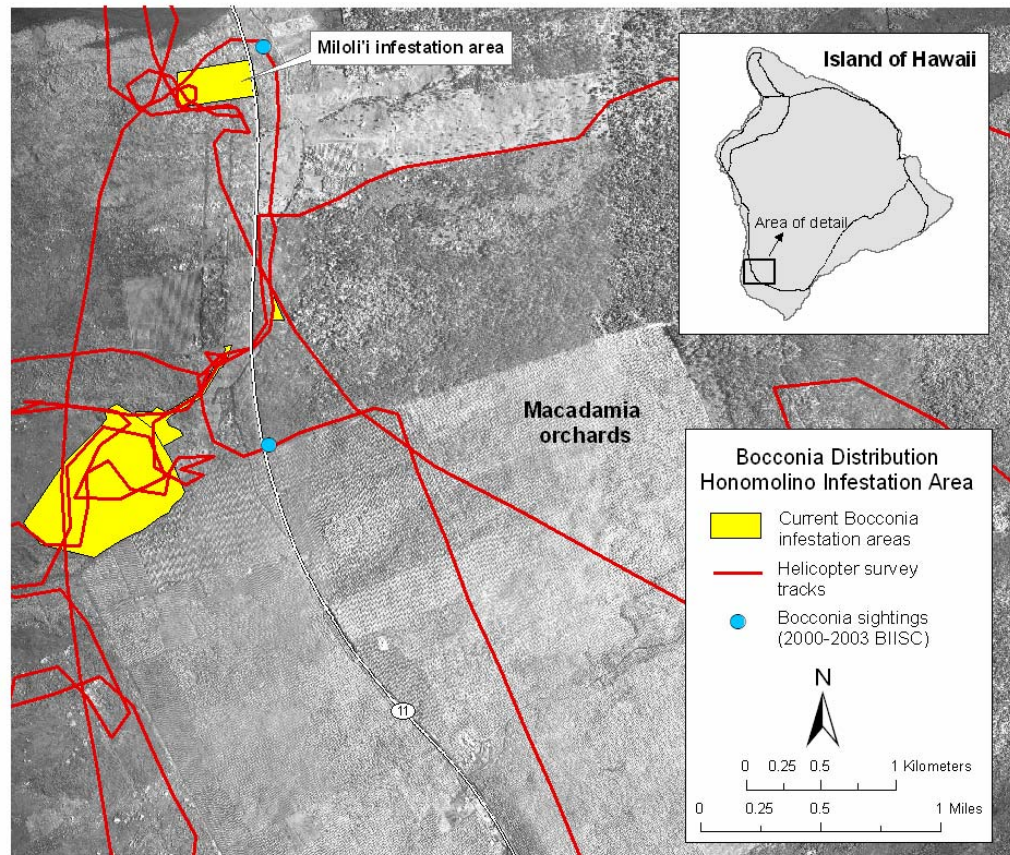


**Figure 8.** Manukā survey area and core area of *Bocconia* infestation



## Honomolino

Four populations of *Bocconia* were detected near Honomolino, infesting 82 ha. (Figure 9). The elevational range for these populations was 320 to 530 m above sea level.



**Figure 9.** Overview of Honomolino survey area showing helicopter transects and locations of current and former *Bocconia* infestations.

Honomolino's largest population consisted of 500 plants, as estimated from an aerial survey. It was located to the north and east of extensive macadamia-nut orchards, and was distributed across 63 ha of pasture, dry-shrub lands, and roadsides, between 320 and 490 m elevation (Figure 9).

A second population was located in similar habitat adjacent and to the northeast of the large parcel described above. Based on a helicopter over-flight we estimated that this area of six hectares harbored approximately 400 individuals.

A third infestation at Miloli'i consisted of approximately 100 plants distributed over 12 ha along a residential road on the ocean side of, and along Highway 11 (Figure 9). Many of the plants were mature and bearing fruiting panicles. These plants were observed growing in residential lots, roadsides abutting dry-mesic 'ōhi'a forest, and vacant lots

with dry-land shrubs. Individuals occurred sporadically along Highway 11 in the vicinity of this residential area.

A single juvenile individual was encountered and pulled from along a side road near the Ho'omau Ranch. Several plants were found and treated at this location by BIISC crews in 2002. A search was conducted on the ground and aerially, including sites where BIISC reported *Bocconia* in 2002, but no *Bocconia* was encountered.

## DISCUSSION

### Wood Valley

*Bocconia* is a severe pest within young (5 to 10 m height) *Eucalyptus* plantations in Wood Valley as evidenced by densities exceeding 1,000 individuals/ha in the south and western *Eucalyptus* parcels. *Bocconia* densities are generally lower in the higher elevation north and east *Eucalyptus* parcels. The most severe infestations observed in Wood Valley occur approximately four km downslope of where the species is thought to have been initially planted, near an old flume house, adjacent to the Ka'u Forest Reserve (Gordon Cran, Personal Communication 06/14/2005).

Additional work is necessary to investigate why *Bocconia* is less abundant in *Eucalyptus* sites closer to its introduction area than at the lower elevation *Eucalyptus* sites which consist of stands of comparable height. Mature alien forests adjacent to infested young *Eucalyptus* parcels had less severe *Bocconia* infestations, perhaps due to lower light levels and less recent soil disturbance. In mature alien forests, *Bocconia* was most often seen in forest gaps, gulches and pig wallows. This observation is consistent with the reported affinities of *Bocconia* for disturbed habitats (Gentry 1993). As the *Eucalyptus* plantations mature, reduced light levels will likely have a negative effect on *Bocconia* densities. Subsequent monitoring of transects in the *Eucalyptus* parcels will aid in this determination.

Although the cane lands harbor relatively low numbers of *Bocconia*, the ecological implications of its presence there are substantial. *Bocconia* is a prolific seed producer; a single tree in Maui produced 300,308 seed capsules in a single fruiting season (Chimera 2003). Thus, scattered *Bocconia* plants in the cane lands could lead to a dense accumulation of seeds in the soil. As *Bocconia* thrives in disturbed sites, a disturbance such as cane removal and bulldozing could lead to a flush of *Bocconia* at infested sites. Such dynamics should be considered in conjunction with seed viability when determining future management of these parcels.

*Bocconia* was not observed invading closed-canopy native mesic forest. The dense shade cast by native tree species and the alien/native shrubby and herbaceous species appear to prevent the establishment of *Bocconia*. Although two immature *Bocconia* plants were encountered and removed in the Ka'u Forest Reserve in 2002, no additional plants were observed in the vicinity. These plants were located in a disturbed area (jeep trail) not



representative of the forest. This trail and all roads leading out of the infestation area should be monitored in the future.

*Bocconia* infests a mosaic of habitats in Wood Valley, principally in the eastern half of the township. Very low to trace densities of *Bocconia* are found along the western edge of the infestation. In the absence of management, *Bocconia* will likely invade the remainder of Wood Valley which comprises abandoned cane lands, pasture lands, residential and agricultural lots and alien woodlands. These lands are ecologically similar to areas of Wood Valley already invaded by *Bocconia*. Wood Valley is bounded by steep canyon walls to the west, north and east. A corridor of pastureland exists to the west around the canyon walls; *Bocconia* could potentially encroach into this area and subsequently escape into surrounding farmlands and valleys.

*Bocconia* is frequently encountered in gulches below Wood Valley, where seeds were presumably washed down during heavy rains in November 2000. It is in these gulches that *Bocconia* reaches its lowest distributional elevation (350 m) on Hawai'i. Although densities are low at these sites, *Bocconia* is adapted to bird dispersal, and these populations are the most likely threat to the plant communities within HAVO due to their proximity.

## **Manukā**

The *Bocconia* population at Manukā is of limited distribution (34 ha) and of low densities (30 individuals/ha). It is curious that *Bocconia* has been slow to spread at this site, given that it was detected over 20 years ago (L. W. Pratt, personal communication, 2002) in a roadside survey of the area. The *Bocconia* population at Manukā occurs in a managed natural area with native plant communities, but has not yet become an aggressive invader. However, this population is not contained by natural features, and the vegetation surrounding the infestation is of similar stature and composition as that observed within the infested area. Eradication of *Bocconia*, which appears feasible at this site, will protect managed resources and will prevent the spread of this species into new areas.

## **Honomolino**

*Bocconia* infests several clusters in the Honomolino vicinity, including rangelands, native forests and residential areas. Although densities are relatively low, there is ample opportunity for this species to disperse into habitat outside of the present infestation, or to increase its densities within its present range. Additional monitoring will help determine the threat *Bocconia* poses to these habitats.

## SUMMARY AND RECOMMENDATIONS

*Bocconia* was present within three infestation areas of the Island of Hawai'i: Wood Valley, Honomolino and Manukā. *Bocconia* was distributed across 1,638 ha. Elevational ranges of the infestations were from 350 to 1,005 m. Both of these elevational extremes were recorded at Wood Valley. The most severe infestations were observed within young (5-10 m in height) *Eucalyptus* plantations in Wood Valley. Lower population densities were observed in mature alien forests. *Bocconia* was more abundant in forest canopy gaps, roadsides and streambeds than in adjacent undisturbed areas, thus an affinity for high light levels and soil disturbance is suspected. Cane lands harbored mature *Bocconia* at much lower densities than *Eucalyptus* plantations (less than 100 individuals/ha versus greater than 500 individuals/ha). Disturbance of infested cane lands can be expected to favor a flush of this fast growing species. *Bocconia* was generally not observed in native, closed-canopy `ōhi`a and koa forests. *Bocconia* infestations within gulches oceanward of Highway 11 are the greatest threat to managed native plant communities in HAVO due to their proximity and dispersal mechanisms. Native forest and open shrubland harbored relatively low plant densities in the Manukā and Honomolino sites. *Bocconia* is most abundant along roadsides, rangelands and residential areas in the south Kona district.

Based on distribution data from Maui, where *Bocconia* infests leeward environments between 152-1768 m (Starr et al. 2003), suitable habitat exists for *Bocconia* to expand its range on the Island of Hawai'i.

### Wood Valley Recommendations

We recommend containment for Wood Valley with the following specifications:

- Eradicate outlying populations to contain *Bocconia*. Nineteen outlying populations in Wood Valley contain an estimated 305 plants, and control is feasible because the sites are accessible. Since most outliers were mapped from a helicopter, some populations may have escaped detection, thus control work along the population's perimeter would also identify overlooked individuals.
- Eradicate *Bocconia* in oceanward gulches. All gulches on the ocean side of Highway 11 containing *Bocconia* should be controlled, and all gulches that pass through the infestation area should be swept and controlled between 152 and 420 m elevation. This strategy will limit *Bocconia* spread in lower elevations.
- Control *Bocconia* in Wood Valley Township. Private landowners and volunteer groups could reasonably control *Bocconia* across much of its range in Wood Valley. Additional support could come from local, state and federal government sources.
- Monitor *Eucalyptus* plantations. The core *Eucalyptus* populations should be left untreated, as control work is likely prohibitively expensive in areas with high infestation rates. Monitoring will provide valuable information regarding the fate of this weed as the surrounding timber matures.
- Implement an aerial monitoring program. This will prevent *Bocconia* from expanding its range by providing location data for outlying individuals.

Monitoring should include the areas between the gulches on the ocean side of Highway 11 and the western boundary of Hawai'i Volcanoes National Park. The western edge of Wood Valley should also be included.

- Implement decontamination protocols. Proper decontamination of heavy machinery used in Wood Valley should prevent the transport of seeds to new areas. Soil movement from infested areas should also be discouraged, by posting signs near the infested areas and notifying contractors and landowners of the threats posed by soil contaminated with *Bocconia* seeds.

## **Manukā Recommendations**

We recommend eradication for the Manukā populations with the following specifications:

- Eradication of *Bocconia* in infested area. Control is feasible and, if resources permit, the infested area should be swept by ground crews at 1-2 year intervals. Eradication will prevent the potential spread of *Bocconia* and invasion of neighboring native plant communities.
- Implement an aerial monitoring program. *Bocconia* is easily detectable at this site, and aerial monitoring is a cost effective means to detect new outliers and assess the effectiveness of control.

## **Honomolino Recommendations**

We recommend eradication for the Honomolino area with the following specifications:

- Notify private landowners. Landowners (residential and agricultural) whose parcels contain *Bocconia* should be contacted, and control work should be initiated. The three identified clusters should be eradicated. Previous sites where *Bocconia* was observed should be revisited annually, to prevent additional establishment.
- Implement an aerial monitoring program. This will prevent *Bocconia* from expanding its range by detecting new outliers.

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### Author Note:

A population of five plants was observed at Hawaiian Ocean View Estates in early 2005. One plant was apparently cultivated, and four plants were observed and removed in a nearby 'ōhi'a woodland. Additional surveys and notification of the landowner are recommended.

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## APPENDIX: PHOTOGRAPHIC JOURNAL



**Figure A1.** *Bocconia* growing among five to 10 m tall *Eucalyptus* trees as photographed from ~90 m above ground level. *Eucalyptus* are planted in rows, *Bocconia* is light colored primarily in lower half of the image, a sample cluster of plants are surrounded by a red oval. Of note is prominent aerial signature of *Bocconia*.





**Figure A2.** *Bocconia* in a disturbed habitat, a gulch along the north eastern portion of the infestation. Again, several plants are surrounded by a red oval, and the aerial signature of *Bocconia* is prominent.



**Figure A3.** *Bocconia* growing in *Eucalyptus* plantations. Principal grass in image is guinea grass (*Panicum maximum*).



**Figure A4.** Fruiting panicle of *Bocconia*. All photos by D.M. Benitez.